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INITIATIVES TO REINTRODUCE TIMBER BRIDGES IN THE UNITED STATES OF AMERICA*

USA.

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1. U.S. NATIONAL BRIDGE INVENTORY PROCESS

Due to improved technology and marketing opportunity, a strong effort is underway to reintroduce timber bridges in the United States. In general, a concern exists about and governmental efforts are ongoing for the improvement of the condition of bridges of all types and materials. The Federal Highway Administration, in cooperation with the states, has established and been maintaining a National Bridge Inventory (NBI) for the nation's bridges. The NBI provides a common reference for determining replacement/repair needs.

Data in the computerized NBI primarily reflect the outcome of detailed biannual inspections mandated by the 1968 Highway Act. The Manual for Maintenance Inspection of Bridges [1] issued by AASHTO and FHWA in 1970 established the inspection procedures. Each inventoried bridge is assigned a "sufficiency rating" to be used in prioritizing bridge reconstruction needs. The sufficiency rating reflects three considerations in the following relative percentages

Structural Adequacy and Safety	55%
Serviceability and Functional Obsolescence	30%
Essentiality for Public Use	15%
	100%

Higher priorities for replacement/rehabilitation funds are given to bridges with the lower sufficiency ratings. Bridges rated 50 to 80 are eligible for rehabilitation. Those rated below 50 are eligible for replacement. Bridges must have a length greater than 20 ft to qualify for either category. Lists of eligible bridges are compiled by each state. States compete for funds made available through the Federal

Highway Bridge Replacement and Rehabilitation Program (HBRRP). Minimum and maximum limits exist for the percentage of annual federal funds any state may obtain. Legislation also directs that a minimum of 15 percent and a maximum of 35 percent of federally apportioned funds be expended for bridges off the Federal-aid system.

The HBRRP provides funds for replacement or rehabilitation of "structurally deficient" and "functionally obsolete bridges." Structurally deficient bridges include bridges posted for vehicles lighter than designed for, closed or in need of immediate rehabilitation to remain usable. Functionally obsolete bridges have deck geometry, load carrying capacity, clearance or approachway configurations inadequate to safely provide the intended service. Based on assigned sufficiency ratings these bridges are designated as eligible for either replacement or rehabilitation. The early 1983 breakdown of HBRRP eligible bridges (of all types and materials) is:

	Bridges Eligible for Replacement	Bridges Eligible for Rehabilitation	TOTAL
Federal-aid	27,304	35,492	62,796
Off-system	123,698	51,352	175,050

The estimated cost of these replacement/rehabilitation needs is estimated at $48.9 billion. The off-system bridges alone require $22.2 billion.

2. CONDITION OF TIMBER BRIDGES

(a) National Roadways

Global examination of the NBI data indicates a pronounced need exists to upgrade timber bridges on national roadways. As of August 1983, a total of 566,443 bridges had been inventoried with the following results:

	On Federal-Aid System	Off Federal-Aid System	TOTAL
Number of Bridges	262,268	303,175	565,443
Percent of Total	46%	54%	100%
Number of Timber Bridges	9,771	61,428	71,199
Percent of Timber Bridges	14%	86%	100%
Percent of Total	4%	20%	13%

A 1982 Department of Transportation report indicated 76,589 bridges, Federal-Aid System bridges and 129,239 Off-System bridges were constructed before 1940. This constitutes nearly 40 percent of the bridges inventoried at the time. Since these bridges have exceeded realistic service life expectations, many are structurally deficient or functionally obsolete.

The Committee on Timber Bridges of the American Society of Civil Engineers is presently conducting a search of the NBI to establish specific timber bridge needs. Based on the August 1983 breakdown of timber bridge frequency, a reasonable expectation is that 4 percent of the Federal-aid timber bridges (2,500 bridges) and 20 percent of the off-system timber bridges (35,000 bridges) are eligible for reconstruction funds. The search will determine the number eligible for replacement and rehabilitation. In turn, these will be sorted by type of construction and compiled on a state-by-state basis.

(b) U.S. National Forests

The USDA Forest Service (FS) is a significant user of timber bridges for roadways. It maintains over 11,000 road bridges and adds 100-250 bridges to the system annually [3]. About 55 percent have all-timber superstructures. The number, profile of types of bridges, and use of timber varies considerably between the nine FS regions. Age statistics about these bridges are not compiled, but one casual indicator is the use of contemporary glulam is less than 5 percent in six regions (but 20 percent, 39 percent and 75 percent in the other three regions). Admittedly, unfavorable economics of glulam partially accounts for these statistics. Also, low-volume traffic has contributed to longevity of many bridges. Despite this, FS officials report new or replacement bridges are required at a rate of 270 per year at a cost of $10 million.

A primary contributor to deterioration of FS bridges is an inability to provide regular, thorough maintenance. Lack of budget funds typically places maintenance at low priority and rehabilitation even lower. Service life is considered fulfilled if 30 years of use are realized. Rotted deck laminations, excessive maintenance needs, loss of tightness, impaired load distribution, delamination and asphalt deterioration are major reasons for electing to replace, the first two being the most compelling. Usually, glulam deck is used in "deck only" replacements. However, complete superstructure replacements are typically steel girders with concrete deck. Funding availability, relative condition of troubled bridges, and economics vis-a-vis increased timber haul feasibility are critical elements in the decision process.

Given the inadequacy of annual maintenance funding, the FS is seeking methods to both maximize the service life of their existing and new bridges and still rely on timber as a major material. Field evaluation of in-place bridges; examination of national maintenance rehabilitation and repair (MRR) needs, and technology transfer are key directives in the process. Abandonment has seldom been an option with reposting or redefining the use of the accessed land being preferred. On logging access roads, completion of or discontinuation of logging typically renders bridges completely safe for remaining traffic.

3. INSPECTION, MAINTENANCE, REHABILITATION AND REPAIR ACTIVITY

(a) Inspection of Experimental Bridges

In the summer of 1983, the author served as the leader of a unique inspection study made of 18 experimental timber bridges in the U.S. National Forests. Constructed in the late 1960's and early 1970's in coordination with the U.S. Forest Products Laboratory, the various timber bridges contained special features expected to improve performance. The bridges were built in various national forests in seven states and varied in length from 20 to 168 feet (20- to 73-ft individual spans). The number of spans ranged from one to four. Primarily, they were constructed (or reconstructed) with transverse glued-laminated (glulam) panel decks and a variety of interpanel connections. Some bridges had either existing or new nail-laminated (nail-lam) decks for comparative purposes. Different types of members, construction and materials were used in the remainder of the superstructure and substructure. The two-fold objective of the study was: (1) to assess the in-place performance of timber bridges, and (2) to examine patterns of moisture content in order to assess the merits of dry-use versus wet-use design stresses. Extensive and detailed results have been reported [7] and will be published [9].

Overall, the inspected bridges were in excellent structural condition. Typically, roadway conditions were excellent, providing for smooth passage regardless of surfacing. There was extensive asphalt cracking only where the surface was unusually thin. Evidence of deterioration either due to propagation of cracks or presence of potholes was rare. Dowel-connected deck panels were tightly mated.

In these bridges, glulam decks generally provided a more effective roof over stringers than nail-lam decks but both types had high moisture content. In contrast, the stringers were relatively dry. On average, about 100 moisture content readings (electrical resistance meter) were taken per bridge. Stringer readings in excess of 20 percent were infrequent but the average moisture content in both decking types exceeded 20 percent. For bottom zones of stringers, the moisture content was and would likely remain well below 20 percent. Readings above 30 percent were rare in all components except nail-lam deck. The observations about moisture content strongly suggested modern timber bridges components remain below fiber saturation condition for at least 20 years.

Bottom laminations of glulam stringers had moisture content in range acceptable for use of dry-use allowable stresses. Readings between 13 percent and 15 percent were the norm for glulam and although occasional values above 16 percent were found, the soundness of the material appeared invariant. Except near abutment, dry-use stresses for top laminations were found to be similarly justified. Dry-use stresses for solid-sawn timber were also supported by the findings in this study. Virtually all readings were at or below 19 percent, including in the abutment zone. Conversely, the observations did not support the application of dry-use stresses to any decking regardless of treatment method. As a consequence of these findings, the American Institute of Timber

Construction (AITC) now recommends wet-use stresses for all glulam decks, regardless of treatment type, and dry-use stresses for stringers.

(b) Maintenance, Rehabilitation and Repair (MRR)

During the summer of 1984, the feasibility of rehabilitating nail-lam timber decks was investigated by interviewing FS bridge engineers in the nine FS regions and reviewing available technical literature. Statistics cited in Section 2(b) are extracted from a report on that study [8]. The survey revealed the extent of the needs together with current practices and constraints. The literature survey included an evaluation of technology of potential use to the nail-lam deck MRR needs.

A promising technology, developed in Ontario, Canada, was identified as a potential means of restoring old nail-lam decks by post-tensioning and prestressing new decks [10]. To date the method has been implemented only on longitudinal nail-lam deck bridges for which it was specifically developed, but it may be applicable to transverse decks also. The fundamental concept is promising; however, there are concerns about loss of pretension, need for periodic retightening, effects of humidity, and initial costs. Also, the variety of timber constructions identified as existing in the FS is exhaustive. Inventories of the individual regions differ considerably as do the inherent MRR needs. Four prerequisites to developing a needed national MRR initiative were recommended:

1. Computerization of the bridge inventory to put statistics on bridge condition in a common format and identify and clarify needs.

2. Workshops to disseminate information to administrators, engineers, and maintenance personnel.

3. Demonstration projects to display and evaluate new methods and technologies, such as the Ontario prestressing procedure. The Forest Service has several sites which are well suited to such projects.

4. Development of a long-term program modelled after the Ontario Ministry of Transportation's successful efforts to upgrade timber bridges [5].

The Forest Service is proceeding with a long-term program which will include field surveys of current conditions, economic studies, experimental and theoretical development of new rehabilitation concepts, and finally dissemination of the new methods to the appropriate audience. There are plans to demonstrate the post-tensioning concept in the construction (or reconstruction) of five or six bridges on National Forests in fiscal year 1986. In addition a novel truss-framed, prestressed timber bridge will be built in 1986. Arranged like parallel-chord floor trusses, it is hoped to increase longitudinal stiffness and allowable lengths for timber bridges.

4. TECHNOLOGY TRANSFER ACTIVITIES

Discussions between the AITC and the U.S. Forest Service in April 1983, concluded use of timber bridges for replacements on secondary and rural roads could be successfully encouraged with developed timber bridge technology. A fact-finding workshop was convened in Milwaukee, Wisconsin in October 1983, to identify actions needed to implement such technology. Knowledgeable professionals from transportation, wood industry, federal government, bridge component suppliers, and national societies reviewed current capabilities and provided advice on needs. The workshop concluded that existing and newly available timber bridge technology could play a vital role in addressing the nation's bridge needs. Consequent to this finding, the FS developed an exhaustive Technology Transfer Plan for Timber Bridges. The stated goal of the program is to increase the use of timber bridges ten-fold in five years. Major components of the plan include:

1. Preparation of a Timber Bridge Design and Construction Manual.
2. Documentation of the cost-effectiveness of timber bridges.
3. Devising bridge railing details that meet AASHTO requirements.
4. Dissemination of information, particularly at the local (state and county) level audience.
5. Execution of demonstration projects in the field.
6. Conduct of extensive national publicity activities.

General objectives are:

1. Inform state, county, and township officials, Federal agencies, engineers, and contractors about the advantages of timber for new and replacement bridges on local and secondary roads and federally-owned properties.
2. Provide guidance on the rehabilitation of existing timber bridges.
3. Cooperate with mutually interested organizations and associations to improve the nation's road systems by providing safe, economical timber alternatives for bridge replacement needs.

5. PENNSYLVANIA STANDARD LOW-COST BRIDGES

To address the extensive and worsening bridge problem in their state, the Pennsylvania Department of Transportation (Penn DOT) undertook development of ready-to-use low-cost bridge design standards for small bridges (18-130 ft span range) [4]. Steel, reinforced and prestressed concrete and timber bridges are included. The plans are approved for federally funded projects. Timber bridge plans are categorized into the 18-35 ft and 30-90 ft span ranges [6]. Each set includes and illustrates, step-by-step procedures for preparing a set of bridge plans from the standards. The user completes data assembly sheets and blank plan sheets based on field information, which become the construction plans. During bid preparation, the contractor can opt to build the structures specified in the contract or develop an alternate-type structure from the standards. Incorporation of the standards in Computer Aided Design and Drafting (CADD) is a future goal.

6. RURAL BRIDGE NEEDS

Timber bridge technology and development is particularly important to rural needs across the United States. Past emphasis on the development of the natural Interstate Highway System economically constrained the individual states' highway dollars, rural roads were virtually ignored in comparison to the Interstate System. About 95 percent of pre-1935 rural bridges (particularly the farm-to-market road system) are still in use. The majority are deficient for current-day heavy agricultural demands. Bridges built in the 1920's typically were designed for 2- and 4-ton truck weights and had 16 ft roadway widths. Contemporary grain vehicles carry 20 tons or more. A bridge road with below 24 ft is now considered deficient. Coincident with this weardown and obsolescence, the abandonment (legal and physical) of more than 45,000 miles of railway since 1940 has gradually, but significantly, placed greater demand on the rural system while the in-place bridges have begin to exhaust their service lives.

Rural bridge needs are concentrated in the short- to intermediate-span range. Simple, lightweight, quickly constructed bridges and bridge components are a priority need and of clear advantage in needed MRR and replacement projects. The thrust of the renewed technology for timber bridges in recent and present years is focused on these aspects. Ability to reuse many existing abutments and piers and to incorporate prefabricated stringers and deck panels limits the closure time for vehicle passage. The 1983 Milwaukee workshop concluded production capability existed in sufficient volume, diversity and geographical dispersion to address the material need nationally.

The mandating of a certain range of proportion of the HBRRP funds to off-system bridge needs is perhaps indicative of federal recognition of the severity of the past funding constraints. Increased motor fuel taxes provided by the Surface Transportation Assistance Act of 1982 gave significant additional federal funding for all state transportation activity. Over half the states have since added their own added fuel taxes. A doubling of the research projects reported at the Transportation Research Board from 1982-83 signaled a spurred interest in highway R&D.

A clear market exists in the rural setting for pronounced use of contemporary timber bridges. Extensive use of all timber bridges in the U.S. National Forests has long underscored their capacity for low volume, heavy-loaded traffic. This is particularly so for roads for access to logging operations where bridges are subject to vehicle weights up to 115 tons. Ongoing technology transfer efforts are intended to convey this capability to state and local (county) bridge officials and, by addressing development needs, enable widespread incorporation of timber bridge elements and structures into their MRR and replacement plans.

7. CONCLUSION

The state-of-the-art of timber bridges in the United States was reported in 1983 [7]. Since that time, documentation of national bridge needs in the United States has brought timber bridges into focus. In rural areas, availability of lightweight, easily erected bridges is essential for improvement of badly deteriorated low-volume secondary roads. In particular, bridges adequate for passage of trucks heavily loaded with agricultural goods is vitally important. Current activity by the timber bridge community centers on establishing and promoting the proven durability and longevity of contemporary timber bridges in such environments.

Efforts are under way to insure widespread use of timber bridge components and standardized systems in a major rehabilitation/replacement program to upgrade the national road systems. Research and development is under way to provide improved components and novel bridge systems having the economics and simplicity needed for rural roads.

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